Technical Report SDD-92-5
(Preliminary)

# MANRATING FEATURES

of the

# SPACE ENVIRONMENT SIMULATION CHAMBERS

at

# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# MANNED SPACECRAFT CENTER

# HOUSTON, TEXAS

by

Donald Furlong
David J. Goerz, Jr.
Franklin R. Mayer

Presented at:

Fifth Annual Symposium
Space Environmental Simulation-
Arnold Engineering and
Development Center

May 21, 1964

Bechtel Corporation, 220 Bush Street, San Francisco, California

TABLE OF CONTENTS

## I. SUMMARY

The Space Environment Simulation Chambers under construction at the Manned Spacecraft Center, Houston comprise two large, man-rated chambers for the training of astronauts and for the testing of spacecraft in an environment simulating some of the parameters of outer space. In addition to the chambers themselves, the facility includes vacuum pumping systems, liquid nitrogen and gaseous helium refrigeration systems, a solar simulation system, control and instrumentation, and all necessary auxiliary equipment.

Man-rating of the chambers involves the manlocks, access arrangements and an emergency repressurization system. For the life support of test subject personnel, environmental control systems are included as well as monitoring systems and surveillance means to collect physiological data and insure safety.

Hazards to which suited chamber subjects are exposed, as well as the physiological results of departure from nominal environmental parameters, are presented as background for the description of the systems and equipment specified for the MSC facility. An important safeguard for chamber personnel is the emergency repressurization system which is described in some detail. The external environmental control systems are also outlined, as well as bio-medical monitoring and surveillance systems.

The incorporation of man-rating adds significantly to the complexity and cost of a simulation facility. Although the primary object of a test may be concerned with a component or a spacecraft, the design of the systems, the equipment configurations, and the test philosophy must reflect the fact that human experimentation is involved. Surveillance and emergency rescue procedures must be established to cover the entire range of potential casualties.

The design of the Manned Spacecraft Center, Space Environment Simulation Chambers represents the engineering solutions reached in meeting the operating criteria and test objectives of the National Aeronautics and Space Administration and in translating these requirements into a practical, useful facility.

## II. INTRODUCTION

### A. GENERAL REQUIREMENTS FOR MAN-RATING

In order to simulate the complex mission of space vehicles at orbital altitudes, government and industry have built and are building space environment simulation facilities. Some of these facilities include provision for man-rating to simulate the effects on man of the reduced pressures and thermal conditions existing in manned space flight.

Significant change from the normal earth environmental parameters of temperature, pressure and gas composition will result in his death, hence a man-rated facility must provide an artificial viable atmosphere for the test subject. Such a man-rated facility allows man in a space suit, with an umbilical or back pack source of life support, to enter an environment of reduced pressures resembling outer space to conduct tests, operate test vehicles, be a subject for the gathering of physiological and psychological data, and learn about and practice space survival techniques.

The incorporation of man-rating adds significantly to the complexity and cost of a simulation facility. The design must include features which insure high reliability for safe human occupancy under normal conditions and safe, efficient egress under emergency conditions. The increased facility equipments required include additions to the chamber such as manlocks and an emergency repressurization system. The peripheral equipments include life support systems, bio-medical monitoring and surveillance systems and medical facilities.

### B. ETHICAL IMPLICATIONS OF MAN-RATING

The responsibilities and ethical implications associated with a man-rated space simulation facility cannot be over-emphasized. Emergency conditions during test periods may logically be expected. Thus, stringent requirements must be met regarding surveillance of the human subject and emergency systems and procedures provided for terminating reduced pressures and other hazardous manifestations of space simulation. The whole test philosophy, procedures, and equipment configurations must reflect the fact that human experimentation is involved even if the primary test objective is concerned with a system or component test.

It is interesting to note that the post World War II Nuremburg Trials resulted in the establishment of ten basic tenets governing the conduct

of research and investigative studies involving human physiological responses and the combined evaluation of man and experimental protective equipment. These basic tenets provide guidance for the establishment of design criteria for manrated space environment simulation chambers.

These ten principles are:

1. Voluntary consent of the subject is absolutely essential. Consent must be based on knowledge and understanding of the elements of the study and awareness of possible consequences. The duty of ascertaining the quality of consent rests on the individual scientist and cannot be delegated.

2. The experiment should seek some benefit to society, unobtainable by any other method.

3. The experiment should be designed and based on prior animal study, the natural history of the disease or problem and other data, so that anticipated results may justify the action taken.

4. It should be conducted to avoid unnecessary physical and mental suffering.

5. No experiment should be undertaken where there is reason to believe that death or disability will occur, except perhaps where the experimenter may also serve as his own subject.

6. The degree of risk should never exceed that which the importance of the problem warrants.

7. There should be preparation and adequate facilities to protect the subject against even remote possibility of injury, disability or death.

8. Only scientifically qualified persons, exercising a high degree of skill and care, should conduct experiments on human beings.

9. The subject should be permitted to end the experiment whenever he reaches a mental or physical state in which its continuation seems to him impossible.

10. The investigator must be prepared to end the experiment if he has reason to believe that its continuation is likely to result in injury, disability or death.

C. HAZARDS

1. General. Hazard categories cover a wide area of possibilities. The physiological consequences, to the extent that they can be predicted, range from mild to critical depending on circumstances. In a space simulation chamber the probability of certain hazards and effects statistically outweigh other eventualities, but emergency and rescue procedures must be established to cover the entire range of potential casualties. Space chamber test subjects are exposed to hazards in the following categories:

a. Impairment of the artificial environment due to a malfunction of the ECS equipment or a failure of suit or helmet pressure integrity caused by a rip, zipper failure or umbilical failure.

b. Chamber operation such as the effects of emergency repressurization, solar radiation, or loss of chamber illumination.

c. Accidents caused by cryogenic spillage from ruptured systems, burns from contact with heating devices, tissue damage from contact with cryogenic surfaces, missile effect of falling objects, fire or explosions of non-compatible materials in an oxygen atmosphere.

d. Errors in judgement or operating procedure by test subjects or by chamber control personnel.

e. Test subject physical impairment due to panic or illness.

2. Nominal Conditions. Under nominal conditions, where the space chamber occupants are not subject to unusual environmental stresses, the ecological parameters are normally maintained in the ranges found in the natural environment of the earth's surface. Exceeding these ranges may produce physiological as well as psychological problems.

(a) Constituent gases. Constituent gases and their partial and total pressures should be as follows:

| | |
|---|---|
| Carbon Dioxide | 0 - 8 torr |
| Water Vapor | 5 - 15 torr |
| Oxygen | 150 - 420 torr |
| Inert Gases | 0 - 560 torr |
| Total Pressure | 155 - 760 torr |

(b) Temperature. With respect to temperature, it is difficult to assign a required range since other factors must be considered in maintaining a comfortable or non-stressing environment. As far as the human body is concerned, air temperature, humidity, air velocity, air density, insulation, and other factors act to produce the sensation of warmth or cold that is experienced. For a chamber occupant his environment should be maintained so that his internal body temperature fluctuation is limited to about $\pm$ 1.0°C.

In a high vacuum environment, the extremely low gas densities in the chamber preclude significant convective heat transfer from the external suit surface. The primary mode is by radiation. However, radiant heat transfer is usually a small percentage of the total. Unless the test subject's environmental control system is capable of metabolic heat removal by ventilation, intolerable suit temperatures will occur, impairing his functions.

(c) Humidity. From the viewpoint of body heat dissipation alone, the range through which relative humidity varies is not controlling, but other considerations make the most desirable relative-humidity range lie between 30 and 70 per cent. For values much below 30 per cent, the mucous membranes and skin surfaces become too dry for comfort and health. For values above 60-70 per cent, there is a tendency for a clammy or sticky sensation to develop.

3. Conditions of Emergency. Emergency conditions are defined as those in which the established range of one or more of the environmental parameters are exceeded, or where some physiological of psychological problem of the test subject arises spontaneously such as heart failure or panic. While all emergency conditions will require some corrective measure, the action taken will vary with the severity of the situation. In some cases, a controlled adjustment of an environmental parameter, such as a

decrease in temperature, may be sufficient corrective action. Other situations will require that the test subject be removed from the chamber in a normal fashion. The most critical circumstances will dictate emergency repressurization of the chamber.

The following are some of the specific bio-medical hazards which must be anticipated:

(a) Rapid decompression. The most extreme bio-medical hazard requiring corrective action is sudden decompression of the test subject because of the speed with which decompression sickness and its attendant symptoms occur. This may result, for example, from accidental rupture of a space suit or depressurization of the test vehicle, exposing personnel to the full vacuum of the simulation chamber.

At an altitude equivalent of 47 torr (63,000 ft.), and at a normal body temperature (37.5°C), the vapor pressure of water is reached. This will, in the unprotected subject, cause body fluids to be vaporized and gases contained in the lungs to be replaced by water vapor. This phenomenon is known as embolism. A person could live for approximately 35 seconds below 47 torr.

If the pressure drop during the decompression phase is sufficiently rapid to create a transthoracic pressure differential of approximately 88 mm Hg. or more, severe damage to the pulmonary tissues is probable, and death from massive hemorrhage may occur. The incidence of bends resulting from expansion of body gases is very high where nitrogen constitutes a significant proportion of the gaseous environment. Circulatory collapse and death are likely to result unless recompression is accomplished in a sufficiently short time.

Therefore, to avoid death from a suit failure, it is imperative that man-rated space environment simulation chambers be provided with the capability for emergency repressurization. This capability must also extend to any manlocks in the facility. Several methods have been evolved for rescue operations such as repressurization of the whole chamber or individual test subject repressurization. The Houston chambers are designed for repressurization of the entire chambers.

As a reasonable procedure, the victim should be recompressed to more than 47 torr within 30 seconds. To prevent the secondary symptoms of hypoxia, further recompression within an additional 15-30 seconds is needed. Recompression to one atmosphere should be accomplished as soon thereafter as possible. The maximum recompression rate may be taken as approximately 1 psi/sec. In the event that bends occur, it may be necessary to apply a pressure of 2-3 atmospheres as quickly as possible. This will require the victim's removal from the space simulator and transfer to an appropriate recompression chamber.

(b) Oxygen Deprivation. Hazards such as rapid decompression, or other failures in the suit-umbilical-ECS circuit will deprive chamber or vehicle personnel of their oxygen supply. Body tissues continue to utilize stored oxygen and anaerobic stores of energy until depleted. Massive disruption of vital cells may occur leading to death. Elements of the nervous system, particularly higher centers in the brain, are highly sensitive to reduced oxygen and will be subject to irreversible damage in several minutes if deprived of external sources of oxygen. Immediate action is required to recompress the subject or to restore a disrupted life-support system. An oxygen partial pressure of 100 mm Hg. is a temporary minimum oxygen requirement.

(c) Carbon Dioxide Excess. In a space suit or test-vehicle cabin, the carbon dioxide partial pressure may increase to dangerous proportions as a result of malfunction of the $CO_2$ removal system. For normal operations, the carbon dioxide partial pressure should not exceed approximately 8 torr. Because $CO_2$ becomes narcotic within several minutes at approximately 75 torr, corrective action should be taken before this level is reached. Early detection of $CO_2$ buildup should provide ample time to remove a chamber or vehicle occupant.

(d) Sound. Noise levels as high as 130 db can be tolerated for periods up to 30 seconds without risk of tissue damage resulting in hearing loss. This is roughly equivalent to the time period required to raise the chamber environment to a life-sustaining pressure. Maximum noise levels would be expected during this phase. Additional helmet and earphone attenuation will raise the tolerance to approximately 140 to 150 db.

(e) Temperature. The wide temperature extremes in the chamber produce the potential problem of frostbite caused by accidental contact with the cryopanels. Skin temperatures of 10°C (for hands) and 13°C (for feet) approximate the threshold for frostbite. Quick removal and treatment of a frostbitten subject is essential.

Failure of a suit heating system could result in an overall cooling of the body. In the absence of protection against heat loss, there is danger of lowering body temperature below the lower limit for survival (25°C). Failure of the cooling system in a space suit ECS may permit the elevation of suit temperature when subjected to solar radiation. Although man has been known to survive body heating to 42°C, the upper limit for optimum physiological functioning is 40°C. In emergencies, the body can tolerate environmental temperatures of 250 to 300°C for four or five minutes. Sufficient time for corrective action should be available.

(f) Other Emergency Considerations. Injuries of varying description and degree may result from accidental falls and falling equipment. The space suit and helmet will serve to lessen the effects of these accidents. Minor or moderate injuries will be best evaluated by the subject himself. The extent of more serious injuries which tend to be incapacitating can be detected by the medical monitor. Nausea and vomiting have serious implications and immediate removal of the subject from the chamber is required. Voice communication from affected personnel will be important in determining the extent of illness.

## III. MSC SPACE ENVIRONMENT SIMULATION CHAMBERS

### A. PROJECT BACKGROUND

In February of 1962 proposals were invited from a number of engineering firms to undertake a study to develop design criteria for space chamber facilities required by the National Aeronautics and Space Administration at Houston. Bechtel Corporation was selected to perform this study which was carried on from March through July of 1962. The results were submitted to NASA in the form of a three volume report covering studies, recommendations, cost estimates and design criteria.

Subsequently Bechtel Corporation entered into a contract with the Corps of Engineers, Fort Worth District, for the design of the Space Environment Simulation Chambers for the Manned Spacecraft Center based on the previously completed study. Design work commenced on September ber 10, 1962 and was substantially completed on August 14, 1963 with the submission of the final package of plans and specifications to the Corps of Engineers. The design was accomplished with the assistance of the following subcontractors and consultants:

| | |
|---|---|
| Air Products & Chemical Corporation | Refrigeration Equipment |
| Chicago Bridge & Iron Company | Vacuum Vessels |
| General Electric Company | Data Handling System<br>Life Support System<br>Bio-medical Monitoring |
| National Research Corporation | Vacuum Systems |
| The Rucker Company | Lunar Plane Hydraulic Drive |
| Dr. Raymond Chuan | Emergency Repressurization Effects |

The design of the solar simulation system was conducted under a separate contract between Radio Corporation of America and the National Aeronautics and Space Administration.

The Space Environment Simulation Chambers are presently under construction at the Manned Spacecraft Center at Houston. Bechtel Corporation maintains close liaison with the Spacecraft Area Office of the

Corps of Engineers at Houston furnishing advice upon request related to interpretation of the plans and specification and providing the services of consultants as required.

## B. DESCRIPTION OF THE MSC HOUSTON CHAMBERS

One of the principal units of the Manned Spacecraft Center is the Space Environment Simulation Chambers facility which will have the capability of simulating the environment of outer space and the lunar surface. This facility will be used for the testing of spacecraft and the training of astronauts in preparation for the Project Apollo manned flights to the moon.

The simulation facility consists of four major structures - the chamber, refrigeration, pump and administration buildings. The chamber building is a high-bay structure of approximately 26,000 square feet which houses two large man-rated space simulation chambers, related services, and work areas. The larger of the two chambers provides simulated space and lunar surface environments and is primarily intended for combined tests involving men and Apollo spacecraft. The smaller space chamber will be utilized for life sciences studies and astronaut training in addition to tests of single modules of the Apollo spacecraft.

The refrigeration building contains the liquid nitrogen refrigeration system, with a 280 KW capacity for the chamber heat sinks. The building also houses two dense gas helium units with a total capacity of 3.5 KW for the cryopumping system in the larger chamber. Adjacent to the refrigeration building, storage is provided for approximately 100,000 gallons of liquid nitrogen. The pump building houses the rough pumping system, repressurization system, service water pumps, air compressors and other auxiliary mechanical equipment. The administration building contains the bio-medical services, the control room, data handling areas and the facility offices.

The larger chamber, shown in Fig. 1., designated Chamber A, consists of a 65-foot diameter vertical cylinder, 80 feet in height with a spherical top head and a bottom head of a semiellipsoidal form. The vessel is constructed of Type 304 stainless steel and has an overall height of 117 feet. The chamber will handle a spacecraft of up to approximately 75 feet in height and 25 feet in diameter.

A side-hinged vertical door for vehicle loading is located in the cylindrical section of the vessel with the bottom of the opening approximately four feet below the lunar plane level. The door provides

a 40-foot diameter clear opening and may be hydraulically opened, closed and clamped from a remote control panel. There are four individually operated 25-ton hoists located above the top head of the vessel. The lifting hooks may be lowered through penetrations in the head during set-up operations in the chamber.

A spacecraft weighing 150,000 pounds may be supported in Chamber A in a vertical position on a rotating platform simulating a lunar plane 45 feet in diameter. The lunar plane rotation ($\pm$ 180°) can be controlled, manually or automatically, to a maximum rotational speed of 1-2/3 rpm. The lunar plane surface temperature is adjustable from 100°K to 400°K by the circulation of liquid nitrogen through the surface panels or by the use of electric heaters under the panels. Instrumentation leads and liquid nitrogen will be conducted through the hollow shaft of the lunar plane assembly.

The interior of the chamber is lined with black, nitrogen cooled, heat sink panels cooled to approximately 100°K. To the maximum practical extent, all surfaces in the chamber viewed by the vehicle consist of heat sinks. Cryopump surfaces, cooled by gaseous helium are shielded from the test vehicle by 100°K liquid nitrogen cooled shrouds.

The chamber vacuum system consists of a combination of mechanical and diffusion pumps and a 20°K cryopump array using dense gaseous helium. The chamber will pump down to $1 \times 10^{-5}$ torr in less than twenty-four hours with a gas in-leak of 27.6 torr lit./sec.

Carbon arc solar simulators of modular design are mounted external to the chamber walls on one side and the top. The simulators irradiate the vehicle through penetrations in the wall at an intensity of 60 to 140 watts/sq. ft. The target area of the side sun is 13 feet wide by 33 feet high, expandable in the future to 20 feet wide by 65 feet high. The target area of the top sun is 13 feet in diameter, expandable to 20 feet in diameter at some future date.

The smaller chamber, designated Chamber B, consists of a 35 foot diameter vertical cylinder, 20 feet high with a hemispherical, removable, flanged head, and a bottom head of a semiellipsoidal form. The vessel has an overall height of 42 feet and is also constructed of stainless steel.

The chamber will handle a vehicle up to a maximum size of 13 feet in diameter by 27 feet high. Vehicle access is provided by the removable top head. A rolling bridge crane with a capacity of 50 tons will be utilized to remove the chamber head or insert test objects in the

a 40-foot diameter clear opening and may be hydraulically op
and clamped from a remote control panel. There are four in
operated 25-ton hoists located above the top head of the vesse
lifting hooks may be lowered through penetrations in the head
set-up operations in the chamber.

A spacecraft weighing 150,000 pounds may be supported in Ch
in a vertical position on a rotating platform simulating a luna
45 feet in diameter. The lunar plane rotation ($\pm$ 180°) can be
manually or automatically, to a maximum rotational speed of
The lunar plane surface temperature is adjustable from 100°K
by the circulation of liquid nitrogen through the surface panel
use of electric heaters under the panels. Instrumentation lea
liquid nitrogen will be conducted through the hollow shaft of t
plane assembly.

The interior of the chamber is lined with black, nitrogen cool
sink panels cooled to approximately 100°K. To the maximum
extent, all surfaces in the chamber viewed by the vehicle con
heat sinks. Cryopump surfaces, cooled by gaseous helium a
shielded from the test vehicle by 100°K liquid nitrogen cooled

The chamber vacuum system consists of a combination of me
and diffusion pumps and a 20°K cryopump array using dense
helium. The chamber will pump down to $1 \times 10^{-5}$ torr in les
twenty-four hours with a gas in-leak of 27.6 torr lit./sec.

Carbon arc solar simulators of modular design are mounted
to the chamber walls on one side and the top. The simulator
irradiate the vehicle through penetrations in the wall at an in
of 60 to 140 watts/sq.ft. The target area of the side sun is 1
wide by 33 feet high, expandable in the future to 20 feet wide
65 feet high. The target area of the top sun is 13 feet in dia
expandable to 20 feet in diameter at some future date.

The smaller chamber, designated Chamber B, consists of a
diameter vertical cylinder, 20 feet high with a hemispherica
removable, flanged head, and a bottom head of a semiellipso
The vessel has an overall height of 42 feet and is also constr
stainless steel.

The chamber will handle a vehicle up to a maximum size of
diameter by 27 feet high. Vehicle access is provided by the
top head. A rolling bridge crane with a capacity of 50 tons
utilized to remove the chamber head or insert test objects i

chamber. A spacecraft weight of 75,000 pounds may be supported on a fixed, simulated lunar plane 20 feet in diameter. The lunar plane surface temperature can also be controlled from 80°K to 400°K. As in Chamber A, the interior of the chamber is lined with black, nitrogen cooled heat sink panels at approximately 100°K. However, no cryopumping is provided. To the maximum practical extent, all surfaces in the chamber viewed by the vehicle consist of heat sinks.

The chamber vacuum system consists of a combination of mechanical and diffusion pumps. Chambers A and B use a common rough pumping system. The chamber will pump down to $1 \times 10^{-4}$ torr in approximately three hours with a gas in-leak of 25.7 torr lit./sec.

The Chamber B solar simulators are the same type as for Chamber A except that Chamber B has a top sun only. The target area for the sun is 5.6 feet in diameter, expandable in the future to 20 feet in diameter.

Figures 2 through 4 show the general arrangement of the facility in plan and elevation with particular emphasis on man-rating features.

## IV. FACILITY REQUIREMENTS FOR MAN-RATING

### A. MANLOCKS

The increased facility requirements for man-rating include additions to the chamber such as manlocks and an emergency repressurization system. Personnel access to Chamber A during testing is through a double manlock at the lunar plane level and a single manlock at the platform level, elevation 31-feet. Additional access during non-operative periods is through the 40-feet diameter side door and by a door at elevation 62-feet which can be incorporated into a future manlock. Access to Chamber B is provided by one double manlock. Each lock unit has a nominal floor area 9-feet by 10-feet for the accommodation of three men. Except for the chamber side doors of stainless steel, the locks are constructed of carbon steel. Figure 5 is a sketch of a double manlock.

The double lock is composed essentially of two parallel single locks with interconnecting double doors. The double lock may be used for astronaut testing exclusive of the main chamber. The doors through the chamber shell are designed to withstand full atmospheric pressure from either side. The exterior doors and the interconnecting double doors in the double manlocks are designed for full atmospheric pressure only on the hinge side of the door. The exterior and interior doors of the single manlocks are designed for full atmospheric pressure on the hinge side only of the door.

All doors are side hinged and provided with quick-acting clamping devices for initial seating of the door seal. The clamping devices on all doors except the doors through the chamber wall are operable from one side only and are a fall-away type which permit the clamps to disengage when the doors become pressure seated.

The inner manlock door is capable of being opened from either inside or outside by a man in a full pressure suit and has quick-opening latches. The outer door is arranged to swing away from the lock and is capable of being opened from the outside only. Doors have a minimum clear width of about 42 inches and a minimum height of 7-feet.

Each manlock in Chambers A and B has its own mechanical vacuum pumping system. The manlocks have the following specified capability:

NASA → Each manlock does not have it own pumping system. Chamber "A" has only 2 manlock pumping systems for 3 locks.

Ultimate pressure of $5 \times 10^{-3}$ torr with a gas inleak of 5.0 torr liters/sec. from the operation of two suited personnel.

Altitude control to maintain test pressure at a pre-set point between 760 torr and 15 torr.

NASA

Maximum descent rate limited to 100 torr/minute.

→ the maximum descent rate of the manlock can be adjusted to 100 TORR/minute

The following equipment is located on each manlock control panel:

Switches to operate the openings of the vacuum system for the manlock with appropriate indicators.

Controls for the altitude control system indicators and recorders of pressure.

Door position indicators.

Valve position control and indicators.

Communications station.

Emergency repressurization switch.

B. REPRESSURIZATION

1. General. Several repressurization systems are provided for the MSC Space Environment Simulation Chambers. Primary emergency repressurization will increase the chamber pressure from $10^{-5}$ torr to 6 ± 1/2 psia (310 torr) total pressure and 4 ± 1/2 psia (207 torr) oxygen partial pressure in 30 seconds. Provision is made to hold the pressure at 6 psia. A secondary emergency system will repressurize the chamber with air from 6 psia to 14.7 psia within 60 seconds additional time after completion of primary repressurization. Fast normal repressurization will raise the chamber pressure from $10^{-5}$ torr to 6 psia in 30 minutes and slow normal repressurization will raise the pressure from $10^{-5}$ torr to 14.7 psia in 6 hours.

The time pressure profile for repressurization has both high and low limits. The maximum time allowable is set by viability limits and is a function of the recompression gas specie. The viable environment depends upon a sufficiently high total pressure

NASA →

**c. Paragraph IV. B. 1. - An additional repressurization schedule will be approximately 8 minutes. Slow normal repressurization is 3 hours not the indicated 6 hours. The gases used for emergency repressurization have not been finally determined.**

and partial pressure of oxygen. The MSC chamber repressurization system is based on the use of two gases: oxygen and nitrogen

An additional consideration in determining the limiting time to attain a viable environment is the interval required for rescue and to reach medical facilities.

A flow schematic diagram for the repressurization system is shown in Fig. 6.

2. Primary Emergency Repressurization. Primary emergency repressurization is accomplished by the rapid release of nitrogen and then oxygen into the chamber from high pressure storage sources. Nitrogen and oxygen are stored at 3300 psi in standby repressurizing gas cylinders. To compensate for possible leakage of gases make up is provided from cylinders at 4000 psi. The make up gas supplies are common to Chambers A and B and the gases are manually fed to the standby gas cylinders whenever the gas pressure falls below limits. To minimize infiltration of moisture and condensation of gases from the atmosphere, the repressurizing gas pipe line immediately connected to the chamber penetrations is connected to a nitrogen supply and maintained at 1-1/2 psia during standby conditions.

At the initiation of repressurization and prior to the admission of oxygen to the chamber, the diffusion pump valves close, the diffusion pump quick cool valves open, the liquid nitrogen shroud inlet and bypass valves open, the helium cryopanel outlet valves close, all mechanical vacuum pumps stop, and low pressure nitrogen is admitted to the diffusion pumps and vacuum lines.

After initiation of repressurization, parallel explosive valves V-1 and V-2 open increasing the differential pressure across diaphragms D-1 to 4 causing them to rupture. The nitrogen is released to flow from standby storage into the chamber. Valves V-7 through V-11 are sequentially opened releasing oxygen. These high pressure valves are connected in parallel for redundancy and to provide necessary capacity. They function as variable restricting orifices to regulate the flow rate, gas velocity, and pressure and maintain a reasonably uniform mass flow.

The nitrogen and oxygen are introduced into the chamber at four places through vacuum valves V-3 through V-6. As the gas enters the chamber, it is diffused through four perforated

C-headers into a plenum space and upward through liquid nitrogen cooled baffles which direct the gas approximately equally to the front and rear of the shroud to prevent excessive dynamic forces on the shroud or test subjects. The perforations in the C-headers are holes 2-1/2 in. diameter spaced at 4-in. centers.

3. Design Considerations.

(a) Temperature. To meet the performance requirements for maximum and minimum temperatures, the timing and gas flow rates in the system must be optimized from theoretical and practical considerations. Three major factors affect the gas temperature in the chamber after repressurization. These are adiabatic or flow work, the Joule-Thomson effect, and surface heat transfer.

Upon initiation of emergency repressurization the gas is allowed to expand from the high pressure cylinders into the low pressure chamber. The gas at the higher pressure begins to cool, due to isentropic expansion, while that at the lower pressures in the chamber begins to increase in temperature. Being non-ideal gases the nitrogen and oxygen also exhibit a temperature drop after throttling from high pressure to low pressure due to the Joule-Thomson effect. As soon as the temperature of the repressurizing gas differs from the surrounding surfaces, such as the vessel walls and cryogenic panels, heat transfer occurs. In the system design, each of these three phenomena were analyzed separately and then superimposed to obtain the final solutions. Figure 7 shows typical pressure, time, temperature relationships after initiation of emergency repressurization.

1. Gas Expansion and Compression. The gas experiences flow work on entering the chamber from the storage system. Therefore, the gas temperature in the chamber rises at the initiation of repressurization. This rise in temperature will be of the order of 200°F. However, there is also a cooling effect due to gas expansion in the storage cylinder. If the gas from the cylinder were allowed to expand indefinitely, the stored gas temperature would theoretically drop to absolute zero. Excessive drops in gas temperature would cause liquefaction and solidification of the gas. By adjusting the retained volume of stored gas the resultant temperature due to the compression and expansion may be limited to a practical value.

2. The Joule-Thomson Effect. The Joule-Thomson effect plays an important role in repressurization utilizing stored high pressure gases. When nitrogen at 80°F is throttled from 3300 psi to atmosphere it will experience a temperature drop of approximately 100°F. The gas temperature at the end of three seconds is determined by the expansion and compression and the Joule-Thomson effect. This temperature is maintained as high as is practical in the present system. However, the temperature of the gas after primary emergency repressurization to 6 psia is primarily determined by heat transfer with the cryogenic shroud.

3. Heat Transfer. The chamber contains large surfaces which behave as an active heat sink to the repressurized gas. The principal surfaces are the liquid nitrogen shroud, helium cryo arrays, and the chamber walls. Figure 7 shows the average gas temperature at the center of the work zone and the cryopanel temperature with and without the addition of heat. It can be expected that the temperature near the cryopanels will be considerably lower than the average.

(b) Gas Heating. To raise gas temperature after primary emergency repressurization means for heating the gas is provided. The system consists essentially of a blower and fin and tube steam heat exchanger. A portion of the repressurizing gas is drawn from the top of the chamber and, after being heated is returned to the bottom of the chamber. The perforated C-headers located in the chamber plenum are utilized for recirculation of the gas.

(c) Dynamic Gas Flow. While problems related to rapid decompression define the pressure time profile necessary in emergency repressurization, other physiological considerations impose additional constraints on the system. Dynamic air pressure encountered by an astronaut during emergency repressurization of the chamber may present problems similar to those experienced by a pilot being ejected from an aircraft. An unrestrained and unprotected astronaut in a space chamber is subject to the hazards of injury resulting from being thrown to the floor, against hard objects or cryogenic surfaces. To minimize the possibility of injuries from these causes, gases are baffled and the dynamic pressures reduced to the maximum practicable extent. The supports and sizing of cryogenic system

elements in the chamber are designed with consideration also being given to the dynamic gas forces involved during emergency repressurization.

(d) Oxygen Compatibility. Consideration has been given to problems associated with oxygen and hot diffusion pump oil during chamber emergency repressurization. The fluid in both the manlock vacuum pumps and in the chamber diffusion and roughing pumps is oxygen compatible to prevent explosion or fire. In addition, all materials in the chamber which may come in contact with an oxygen environment have been selected on a basis of oxygen compatibility. All exhaust or relief lines from the oxygen system are ducted outside the facility building or vented into a safe area.

(e) Other. The rate of pressure increase is limited to a maximum of 0.5 psi/sec. to prevent injury to personnel caused by too rapid pressure changes. To limit further the noise level in the chamber to acceptable levels, a silencer reducer is provided in the repressurization system.

4. Secondary Emergency. Following emergency repressurization to 6 psia, it may be desirable to hold the chamber at this pressure level for a considerable period of time. If the situation requires raising chamber pressure to atmospheric pressure without delay, this may be accomplished within 60 seconds utilizing atmospheric air admitted through valves V-12 and V-13.

5. Normal Repressurization. This system will raise the chamber from $10^{-5}$ torr to 6 psia in 30 minutes or to 14.7 psia within 6 hours as required. Filtered atmospheric air is employed as the repressurizing medium. Air is introduced into the repressurization header through either of two parallel isolation valves, V-14 and V-15, one for a fast rate and the other for a slow rate, and into the chamber through valves V-3 through V-6. The air filter, blower and heater for the normal repressurization system are also used for chamber heating and ventilation.

6. Manlocks Repressurization System. The manlock emergency system has the capability of raising manlock pressure to 6 psia within 30 seconds and to one atmosphere within approximately 90 seconds. To repressurize a manlock, atmospheric air is admitted through a filter, restricting orifice, vacuum valve and T-header. To minimize acoustic level and pressure shocks, the T-header is perforated and located below the floor inside the

manlock. The repressurizing air is then directed through slotted openings along the side walls.

## C. CONTROLS

Separate, independent repressurization control systems are provided for the main chamber and for each manlock. The design provides for the initiation of emergency repressurization by loss of space suit pressure or by the actuation of a switch on the bio-medical control console. Suitable baro-switches and circuitry in the space suits can be provided to initiate repressurization upon loss of suit pressure. Redundancy to ensure system reliability is provided by utilizing two independent circuits.

To avoid false tripping in case of baro-switch failure, the system is designed so that repressurization is initiated only if two of the three baro-switches in the same suit make contact. For manual operation of emergency repressurization console switch contacts are connected in parallel with the baro-switch relay contacts and produce an essentially identical sequence.

Provision is made for a "hold" switch on the bio-medical console which provides the bio-medical monitor with the capability of holding all emergency repressurization functions in the event the monitor has reason to evaluate the extent of the emergency before permitting repressurization to proceed.

## V. LIFE SUPPORT REQUIREMENTS

### A. GENERAL

Life support system requirements for the Space Environment Simulation Chambers include specialized equipment and dependable operating procedures. The equipment includes: the ECS, or environmental control system, which produces, regulates, maintains and delivers the ecological environment for the subject; the control, instrumentation and data handling system which monitors, controls and records bio-medical and life support data associated with the subject; and the surveillance system which provides constant monitoring of the subject. In addition, but outside the scope of this project, life support requirements include the space suit, helmet and umbilical connections which enclose the subject and protect him from the hostile chamber environment. Also required are medical equipment and procedures to "pre-flight" examine the subject, affix bio-medical sensors, suit the subject and test space suit integrity, "post-flight" examine and treat the subject and provide emergency treatment in case of accidents.

### B. ENVIRONMENTAL CONTROL SYSTEM

1. General Description. The ECS provides all basic life support requirements for personnel wearing space suits and subjected to pressures from one atmosphere to high vacuum. Several techniques have been considered to provide the basic functions. The internal system based on a self-contained back pack is described in a later section for future use. The external system using an umbilical cord is the primary system for the Space Environment Simulation Chambers at Houston.

The ECS system is a closed loop, single gas system which provides breathing and ventilating oxygen to suited subjects through umbilicals connected to penetrations in the chamber and manlock walls. The oxygen is recirculated and conditioned in a closed cycle system to control and monitor total pressure, carbon dioxide partial pressure, temperature, flow and relative humidity. A flow diagram for a typical ECS is shown in Figure 8.

An ECS includes all the mechanical equipment external to the chamber or manlock which supplies the conditioned gas to the chamber penetration and the necessary instrumentation and control of the system. The mechanical equipment includes the external interconnecting lines, penetration fittings or closures and ECS modules.

2. Requirements. Following are the performance requirements established for each ECS.

a. The system will have a cooling capacity of 2000 Btu per man.

b. The system will be designed for a total umbilical-pressure suit pressure drop less than 2.0 psi.

c. The system will provide gas flow per suit up to 20 cfm at up to 20 psia, equal to 144 lbs/hr.

d. The breathing and ventilation gas will be pure oxygen.

e. The system will provide suit operating pressures between 3.5 and 5.0 psia.

f. The system will provide gas inlet temperatures from $40^{\circ}F$ to $70^{\circ}F$ and variable relative humidities.

g. The system will provide a $CO_2$ partial pressure below 8 torr.

3. ECS Modules. Eight ECS modules are provided for the facility. Each module will function over a pressure range from 14.7 to zero psia and may be used for either chambers or their manlocks. Each module will supply the requirements for three test subjects. Parallel ECS modules are connected to each chamber and manlock and each module is connected to all penetrations in chamber or manlock respectively.

Chamber A will have ten active ECS penetrations and four blanked off (for future upgrading). Six ECS penetrations are accessible at the lunar plane elevation and four are located at elevation 31-feet. Chamber B will have six ECS penetrations at the lunar plane elevation. Each of the manlocks (three on Chamber A and 2 on Chamber B) will have two penetrations which will support three test subjects. Each ECS module consists of the following oxygen compatible equipment:

a. Positive displacement blower to provide circulation.

b. Heat exchanger and refrigerator to cool gas and condense moisture.

c. Carbon dioxide absorbers in parallel to provide capacity for regeneration.

d. Mechanical vacuum pump to evacuate module or components prior to filling with breathing oxygen.

e. After cooler and heater to control gas temperature to test subject.

f. Oxygen storage for normal and emergency make-up.

g. Instrumentation for control and monitoring of critical parameters such as temperature, flow, carbon dioxide partial pressure, etc.

4. Operation. The operation of a chamber ECS is described as follows:

Prior to connecting a suit umbilical the system is evacuated with the vacuum pump and repressurized with breathing quality oxygen. The oxygen for normal make up and filling is stored in two 2000 psi cylinders, each containing approximately 16.5 pounds. A supplemental storage consisting of four oxygen cylinders provides increased capacity necessary in the event of suit or umbilical failure during an operational run. The oxygen is supplied to the system ahead of the blower.

During normal operation the absolute pressure control valve V-1 maintains a pre-set pressure at the inlet to the blower by regulating the oxygen flow from the make-up oxygen supply. In the event of an increase in chamber pressure above 0 psia, the differential pressure controller (DPC-1) operates valve V-2 to raise the pressure and maintain a 2.5 psi pressure differential between the inside of the suit and the chamber pressure. In the event of a decrease in chamber pressure DPC-1 opens valve V-3 to reduce the ECS pressure to maintain the 2.5 psi pressure differential. In the event of system rupture, pressure suit failure, or excessive leakage, DPC-1 opens valve V-4 to supply sufficient flow from the emergency $O_2$ supply. The ECS also provides control from DPC-2 to operate PVC valve V-5 to maintain a proper pressure differential across the space suits.

The exhaust gas from the test subject is pressurized by the blower. The flow in a bypass around the blower is automatically regulated to provide the desired pressure drop and flow through the system. After discharge from the blower, the oxygen is cooled in a heat exchanger to lower the temperature and humidity. Excess moisture is condensed and drained into a collection reservoir. Suitable valving allows the condensate to be drained without interrupting operation of the ECS. The oxygen is then passed through a selective filter to absorb the carbon dioxide. Before returning to the test subject the oxygen is cooled and reheated at

each penetration to provide the proper temperature for ventilating flow to each suit. Each suit temperature may be individually controlled.

5. Monitoring. Two identical, free-standing consoles are provided in the Control Room complete with the instrumentation necessary to monitor all environmental control systems corresponding to each chamber and manlock. The consoles are designed to accommodate two seated monitors, one for the spacecraft cabin ECS and one for facility ECS. The following variables are presented on the facility ECS console:

Monitors and alarm lights

Total system pressure
Partial $O_2$ pressure
Partial $CO_2$ pressure
Ventilating $O_2$ flow
Make up $O_2$ flow

Alarm lights only

Emergency $O_2$ storage pressure
Make up $O_2$ storage pressure
Condensate collector level
ECS outlet temperature

The panels on the ECS modules include the following equipment and readouts:

Partial $O_2$ pressure analyzer with indicator
Partial $CO_2$ pressure analyzer with indicator
Supply/return differential pressure controller
Total pressure indicator
Ventilating $O_2$ flow indicator
Switches and lights for instrument power, blower, vacuum pumps, condensing unit and coolant pump.

C. BIO-MEDICAL MONITORING

1. General. Bio-medical monitoring includes the instrumentation and systems of data acquisition for monitoring ecological and physiological parameters of test subjects in the chamber. The purpose of the instrumentation is to acquire data involving human physiological responses for the combined evaluation of the subject and experimental protective equipment, and to permit

surveillance at all times of the physiological, psychological and environmental status of the test subject. Principal elements of a physiological or bio-medical instrumentation system are the sensors on the man and the associated circuits which transmit bio-medical data to the bio-medical control center. See Figure 9 for a typical bio-medical system information flow diagram and control panel definition.

Physiological and environmental parameters are displayed on meters and indicators on the bio-medical consoles in the facility control room. Here, bio- medical monitoring personnel, by surveying the instruments and communicating with the test subject by voice and TV links, are cognizant of his status and can take appropriate action when required to insure his safety. As an added precaution, automatic alarms are provided to sound when parametric values follow unfavorable trends or exceed safe limits.

2. Bio-medical Monitor Console. Two bio-medical monitor consoles are provided in the control room, one for each chamber, furnished with the instrumentation necessary to monitor physiological and suit environmental parameters necessary for the test subject in the space environment. Each console is arranged to accommodate two seated persons. The arrangement permits monitoring six subjects, each with his own corresponding set of vertically arranged instruments. In addition, both end panels of the console are removable so that future consoles modules may be added. Each console is fitted with instruments as follows:

(a) Location Display. A display is provided to show the location of the test subject being monitored.

(b) Subject Identification. A card holder is provided for insertion of the monitored subject's identification.

(c) ECS Module. A card holder is provided for identification of the monitored subject's life support system in use.

(d) Elapsed Time of Test Readout. A five digit display of elapsed time is provided to count the number of one-second pulses and continuously display the elapsed time of a test.

(e) Subject Parameter Meters. Meters with vertical scales, high and low limit sittings, and colored status indicator lights are provided for the following parameters:

Respiration rate - scale 0 to 60 counts per minute.
Body temperature - scale 90 to 105°F.
Suit pressure - scale 0-20 psia.
Partial pressure $CO_2$ - scale 0-20mm Hg.
Suit inlet temperature - scale 40 to 100°F.

(f) Parameter Recorder. A multi-channel, variable speed, oscillograph recorder is provided to accept signals from the subject parameters displayed on the console.

(g) ECG/Blood Pressure Oscilloscope. An oscilloscope is provided for display of either the test subject electrocardiogram wave form or blood pressure.

(h) Chamber Emergency Repressurization Switches. Two switches are provided in the center of the console fact for initiation of emergency repressurization, one is colored red and labeled EMERGENCY REPRESSURIZATION START and the other is black and labeled EMERGENCY REPRESSURIZATION HOLD.

3. Surveillance of Test Subject. One of the most important features of a man-rated space chamber is adequate provision for surveillance of the physiological and psychological condition of the subject. In addition to bio-medical sensors, continuous surveillance of test personnel in the MSC chambers is provided by direct visual observation, by television, and by voice communication.

(a) View Ports. Direct visual observation is the most obvious and least complex method of surveillance. View ports are provided in the chamber and manlock walls to permit observation of test subjects by the test conductor and bio-medical observers. There are nine view ports in the cylindrical portion of Chamber A and four in the top head, one in each of the four top hoist hatch covers. Chamber B contains four view ports. The double manlocks contain ten view ports and the single manlock on Chamber A has five.

Two view ports from the manlock to chamber are provided, one located on the side and the other in the inner manlock door. These are to be used by standby and

rescue personnel in the manlocks for observation during the progress of tests. All view ports are ten inches in diameter, of double walled glass with a desiccant between.

Lighting is provided for the interior of the chambers and manlocks and is connected to the emergency power system to preclude the possibility of failure during test conditions.

(b) Television. Complete closed circuit television systems are provided to permit observation of personnel in Chambers A and B and associated manlocks. The systems consist of cameras, control units and monitors. In each chamber three cameras are placed to view the lunar plane, and one to give coverage of the upper part of the test article. In Chamber A a fifth camera views the walkway at elevation 31-feet. Cameras within the chambers are fitted with zoom lenses and are mounted on remotely controlled pan and tilt units. A fixed lens camera is located outside each manlock to view the interior through a special port.

Two similar consoles, one for each chamber, are provided in the control room for mounting monitors and controls. Television monitors are located at the test conductor's console, bio-medical consoles and television control consoles and are fitted with 10 channel selector push button units to permit switching to selected cameras.

(c) Voice Communications. An operational communication system is provided consisting of multi-point, two-way, voice communication stations located at various control consoles and panels throughout the control room and at other points where control of a test may be exercised. A special feature of the station on each bio-medical console is a series of three pushbuttons which permit private conversations between the bio-medical console operator and any one of the three subjects in the chamber or manlock supervised by that particular station. The test conductor stations are also capable of monitoring the conversations between bio-medical console operators and test subjects.

The communications system normally operates from a 120 volt, 60 cycle supply, but on power failure, an automatic switch transfers the system to a 28 volt, emergency standby battery supply.

## VI. PERIPHERAL EQUIPMENT

### A. MEDICAL FACILITIES

A medical area is included in the facility to support rescue, examination and treatment of test subjects, as well as to provide for normal medical services associated with test operations.

The size of the medical area was determined by the anticipated number of subjects that will be involved simultaneously in a test. The medical area has been located as close as practicable to the test chamber and will provide necessary space for the required examination tables, and such equipment as a respiratory resuscitator, a cardiac monitoring and resuscitation unit, emergency surgical instruments, rolling stretches, drugs, etc. The medical facility should also have a recompression chamber capable of holding one recumbent person and an attendant. This unit is needed in the event decompression sickness does occur.

In addition to the above facilities for emergency procedures, the medical area should also include a test subject preparation area where pre-test physical examinations are conducted, a bio-medical area for fixing sensors to the subject, a space suit area for assisting the test subjects into space suits, and an area for testing integrity of the space suit and bio-medical instrumentation.

A denitrogenation room is included to prepare the test subjects prior to entrance into the vacuum chamber. Here, test subjects in space suits breathe oxygen to purge nitrogen from their bodies and reduce the possibilities of the bends, or decompression sickness.

An air-conditioned, clean area is needed for the proper storage, maintenance and testing of space suits and equipment. The area and facilities must be capable of accommodating the personnel required for the test mission, as well as those standing by for relief or rescue functions.

### B. EMERGENCY POWER

An emergency power source is provided to supply the environmental control systems, the biomedical monitoring systems, and the emergency lighting system. Emergency power automatically comes on the line, supplying these systems in case of a primary power failure to the facility. The system is designed to provide power for the period of time necessary to allow safe exit of personnel from the chamber.

## C. FUTURE REQUIREMENTS

Development work is in progress on portable back pack ECS. The back pack consists of a closed loop, self-contained, self-powered ECS carried by the subject. A microwave link is used for voice communication and bio-medical monitoring. When back packs are in general use, umbilicals may no longer be required. The use of back packs will result in increased mobility for chamber workers and should provide greater flexibility in testing. Back packs will be used in actual space flight, orbital rendezvous and docking and exploration of lunar and planetary bodies, and therefore provision must be included for their testing and use in space simulation facilities.

1. Back Pack Exhaust. The presently conceived back packs continuously exhaust water vapor which results from suited occupant's respiration and other body functions. The exhaust gas load from a back pack is estimated to be about one lb/hr of water vapor. One pound of water vapor per hour represents a virtual condensable leak of 120 torr liters/sec.

(a) Effect on manlock. The introduction of the back pack gas load into a manlock will require special features to permit venting of the manlock to the chamber without causing an excessive pressure rise within the chamber. Two methods may be used to handle back pack exhaust in the manlocks: (1) removal of water vapor from the manlock by exhausting through an umbilical to an external ECS, or (2) removal by condensation through the addition of cryocondensing surfaces connected to the manlock. The operation of back packs in a manlock at higher pressures consistent with the capacity of the pumping system is permissible. However, in this case it is necessary to remove the additional water from the mechanical pump oil of the manlock pumping system by an auxiliary system.

(b) Effect on Chamber. To operate diffusion and cryogenic pumps, it is necessary to evacuate the chamber with a roughing system to a pressure below $1 \times 10^{-2}$ torr. The roughing system is not designed to handle back pack exhaust, hence, auxiliary equipment is required. The back pack exhaust may be connected by an umbilical to the chamber ECS. The ECS may be modified to handle the water vapor. After operating pressure is achieved, and with the heat sink cooled to liquid nitrogen temperature, the umbilical may be disconnected and water vapor exhausted to the chamber walls.

VASA

→ **d. Paragraph VI, C. – Microwave link bio-medical monitoring is not contemplated at this time.**

As an alternate, the back packs may be operated in the chamber below 10 torr during the roughing cycle with the heat sink cooled. The heat sink would condense the chamber water vapor and the back pack exhaust causing frost which would have an effect on environment simulation and test duration. The sources of gas from the back packs are assumed to be at unspecified locations in the chamber. Primary radial molecular diffusion from these point sources will impact on test article walls and on other line of sight surfaces. The water vapor will probably condense as frost, primarily on the inner wall of the heat sink. The cryodeposit will build up on the surfaces and will have a resultant effect on thermal simulation.

The temperature of a vehicle operating in a vacuum environment will depend on the surrounding heat sink temperature and absorptivity. Both apparent heat sink temperature and absorptivity are dependent on the thickness of the cryodeposit. For operating periods up to one month duration, and considering the effects of several back packs operating at one pound per hour discharge rate in a large chamber, the variation in apparent heat sink temperature due to cryodeposits is probably negligible. Variation in absorptivity depends on wave length but is probably negligible.

Back packs will also have an effect on chamber pressure as a function of the ratio of back pack exhaust and heat sink surface area. The diffusion pump stations will be exposed to the vapor evolved. However, only a small amount of gas would escape primary or secondary impingement on the intercepting envelope and would be largely condensed before reaching the pumping station inlets.

2. Communications. Three receiving antennas are mounted inside both chambers for picking up bio-medical data and voice communication from the subjects' back packs. Three separate 8" inside diamter, chamber shell penetrations are provided at 120° spacing above the lunar plane level to permit antenna coaxial feedthrough. The telemetry receiving unit will be part of ground support equipment (GSE) and will provide a continuous D. C. signal of 0 to 5 volts for each subject's measurements desired on the Bio-medical Console. Each of the D. C. signals will be routed by cable from the GSE to the respective Chamber Junction Rack where the signal will enter the existing umbilical wiring system. Mounting plates for antenna support and cable connections to suit the selected antenna will be provided on the work zone side of the cryopanels.

## ACKNOWLEDGEMENT

This paper covers work performed under Contract No. DA-41-443-ENG(NASA)-12 by Bechtel Corporation for the Fort Worth District, United States Army, Corps of Engineers, Colonel F. P. Koisch, District Engineer, Contracting Officer. Lieutenant Colonel Wayne A. Blair, Deputy District Engineer, is in charge of construction. The NASA representative responsible for the Space Environment Simulation Chambers is Richard Piotrowski. The Project Manager for Bechtel Corporation was J. M. McCampbell, succeeded by D. Furlong. Project Engineer was J. Reynolds, Jr. The subcontractors and consultants were Air Products & Chemicals, Inc., Chicago Bridge & Iron Company, General Electric Company - Missile and Space Division, National Research Corporation, The Rucker Company and Dr. R. Chuan.

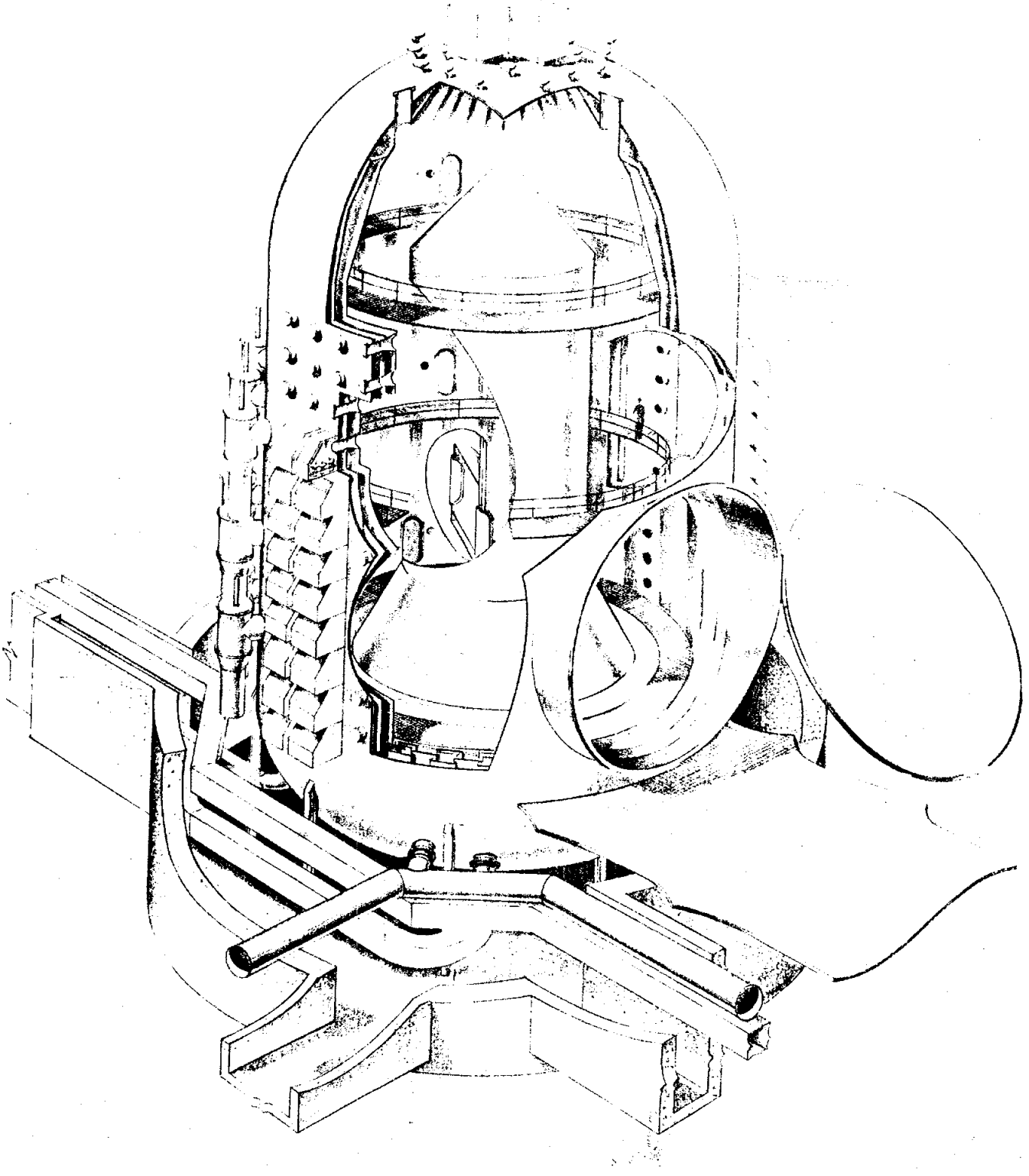


FIGURE 1. ARTIST'S CONCEPTION CHAMBER A
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER. HOUSTON, TEXAS

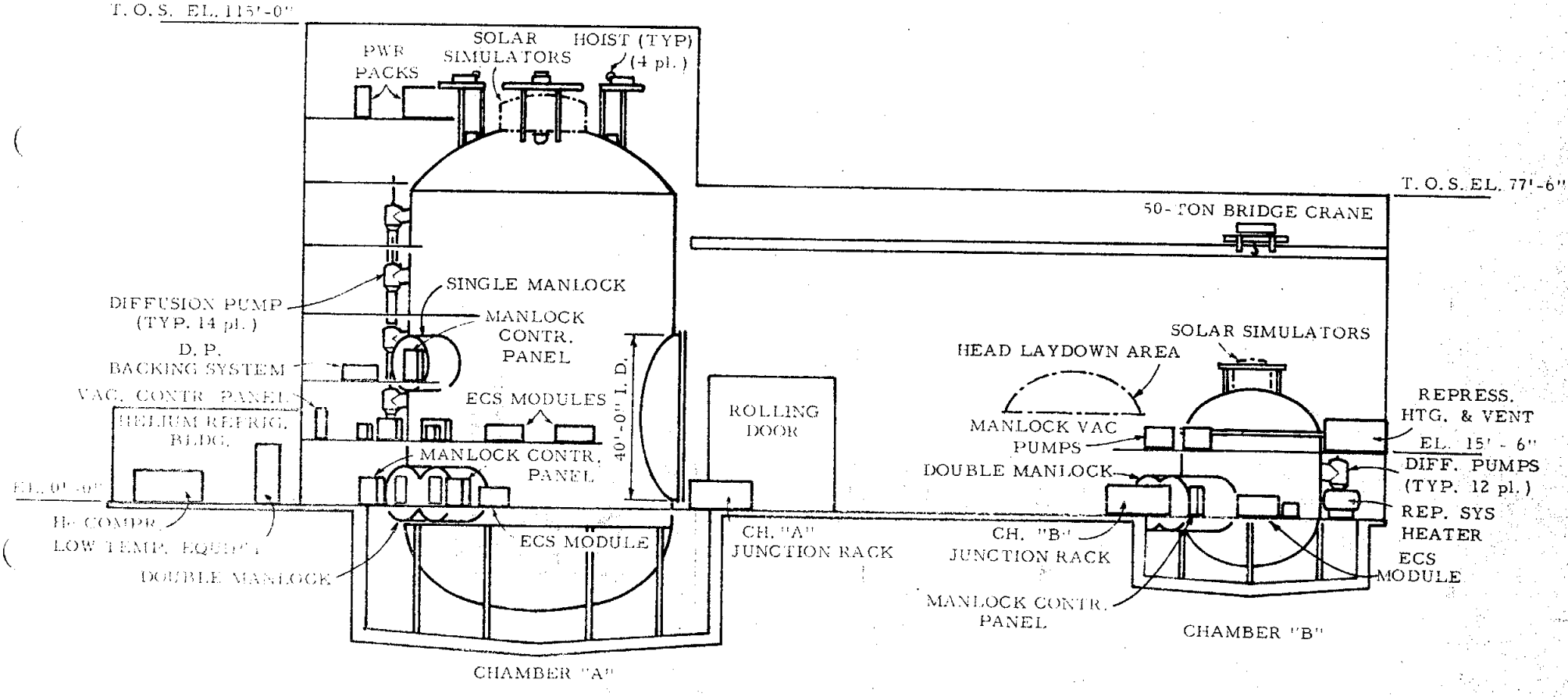



FIGURE 2. LONGITUDINAL SECTION
SPACE ENVIRONMENT SIMULATION CHAMBERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

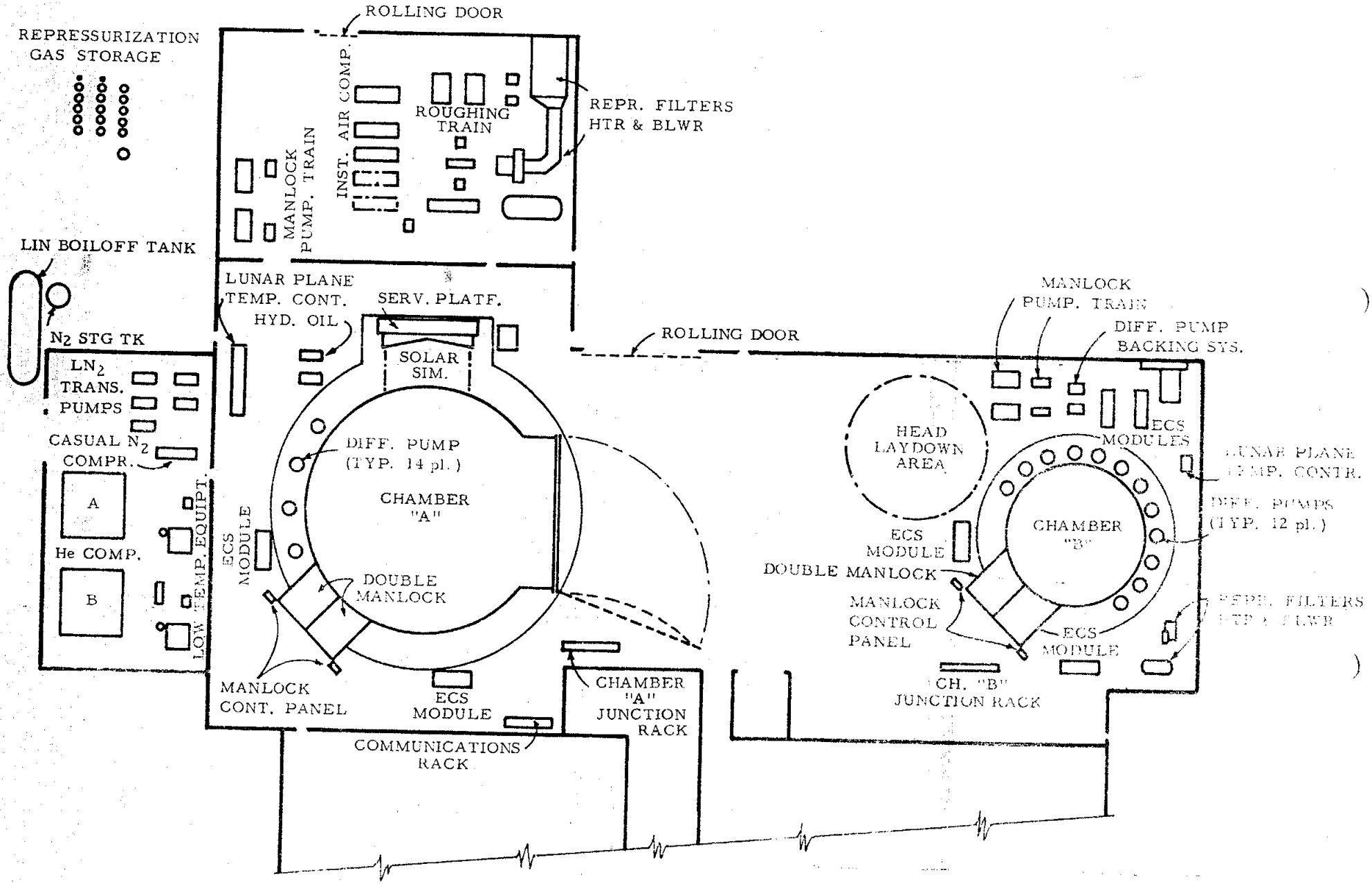



FIGURE 3. PLAN AT ELEVATION 0'-0" (GROUND FLOOR)
SPACE ENVIRONMENT SIMULATION CHAMBERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

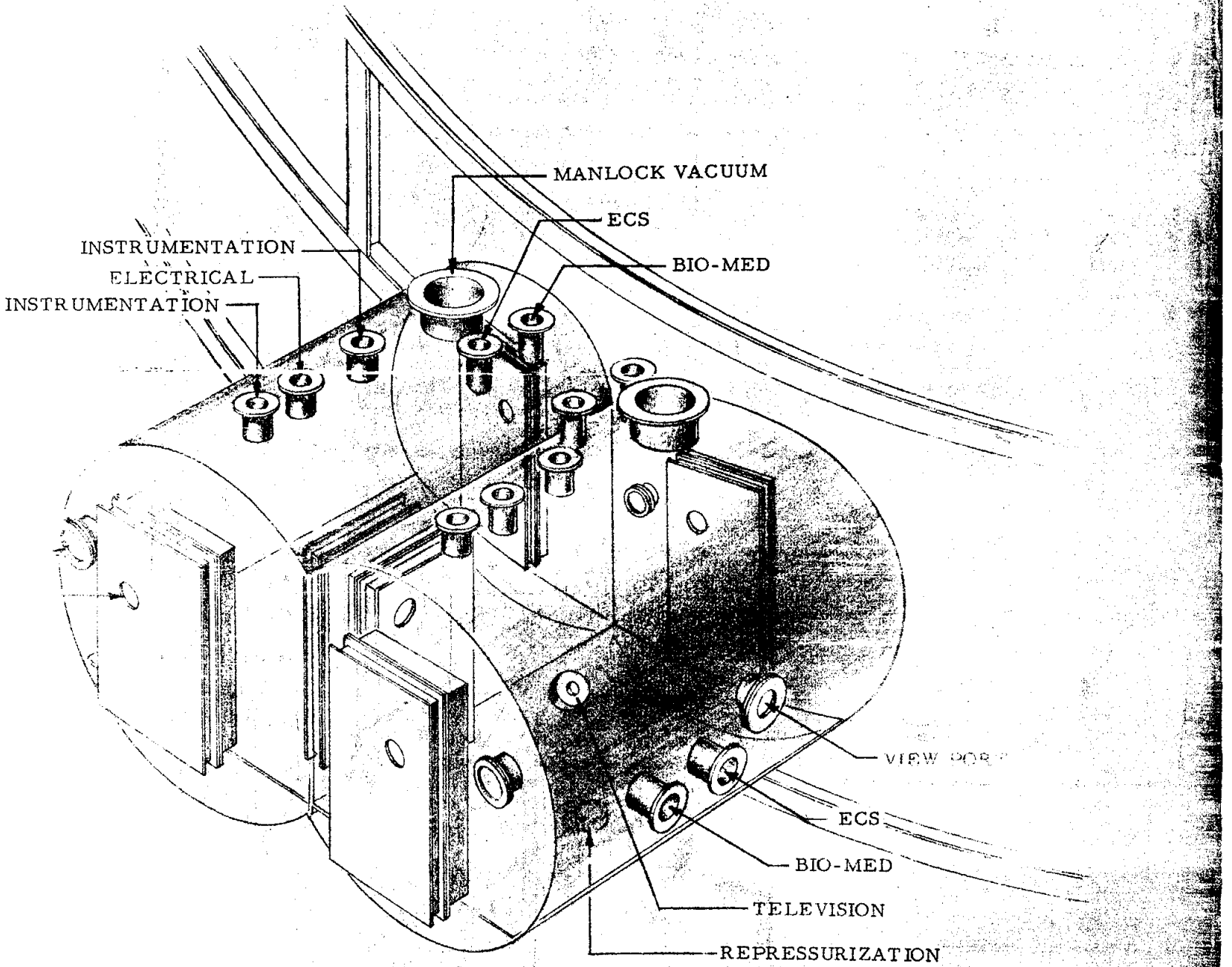
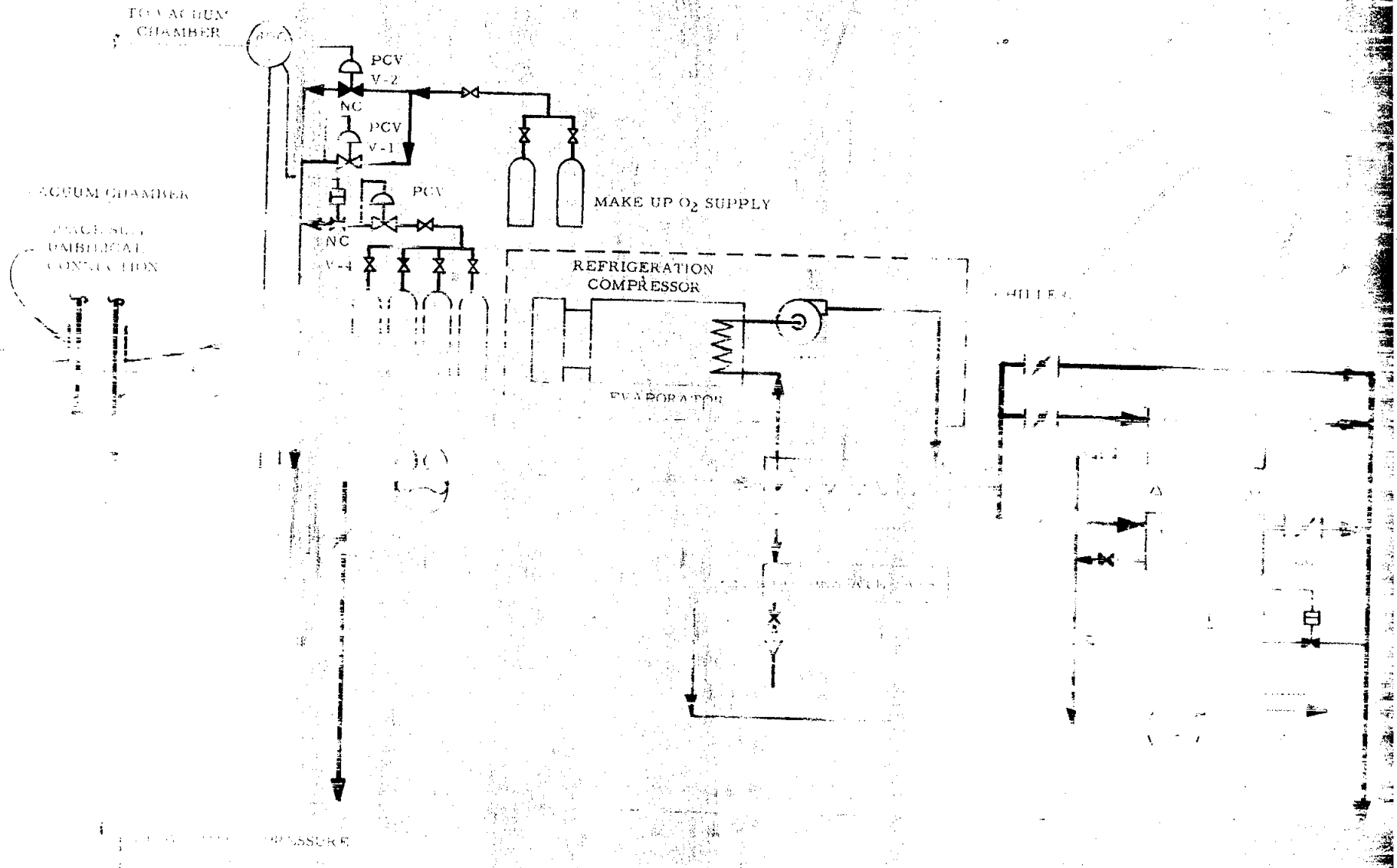



FIGURE 5. ARTIST'S CONCEPTION
DOUBLE MANLOCK, CHAMBER A
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER, HOUSTON, TEXAS




ENVIRONMENTAL CONTROL SYSTEM FLOW SCHEMATIC
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

BECHTEL

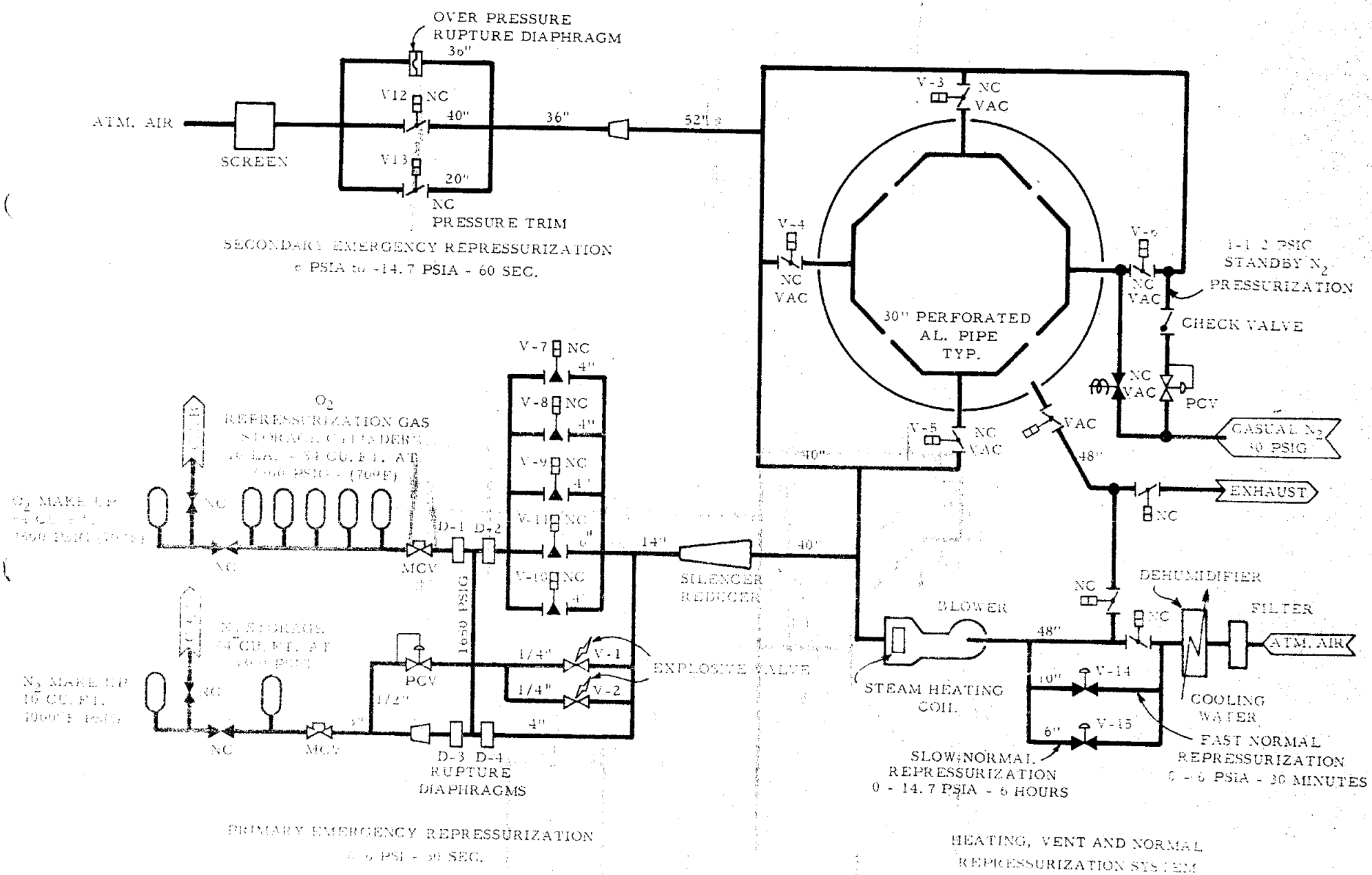



FIGURE 6. REPRESSURIZATION SYSTEMS, CHAMBER A
SPACE ENVIRONMENT SIMULATION CHAMBERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

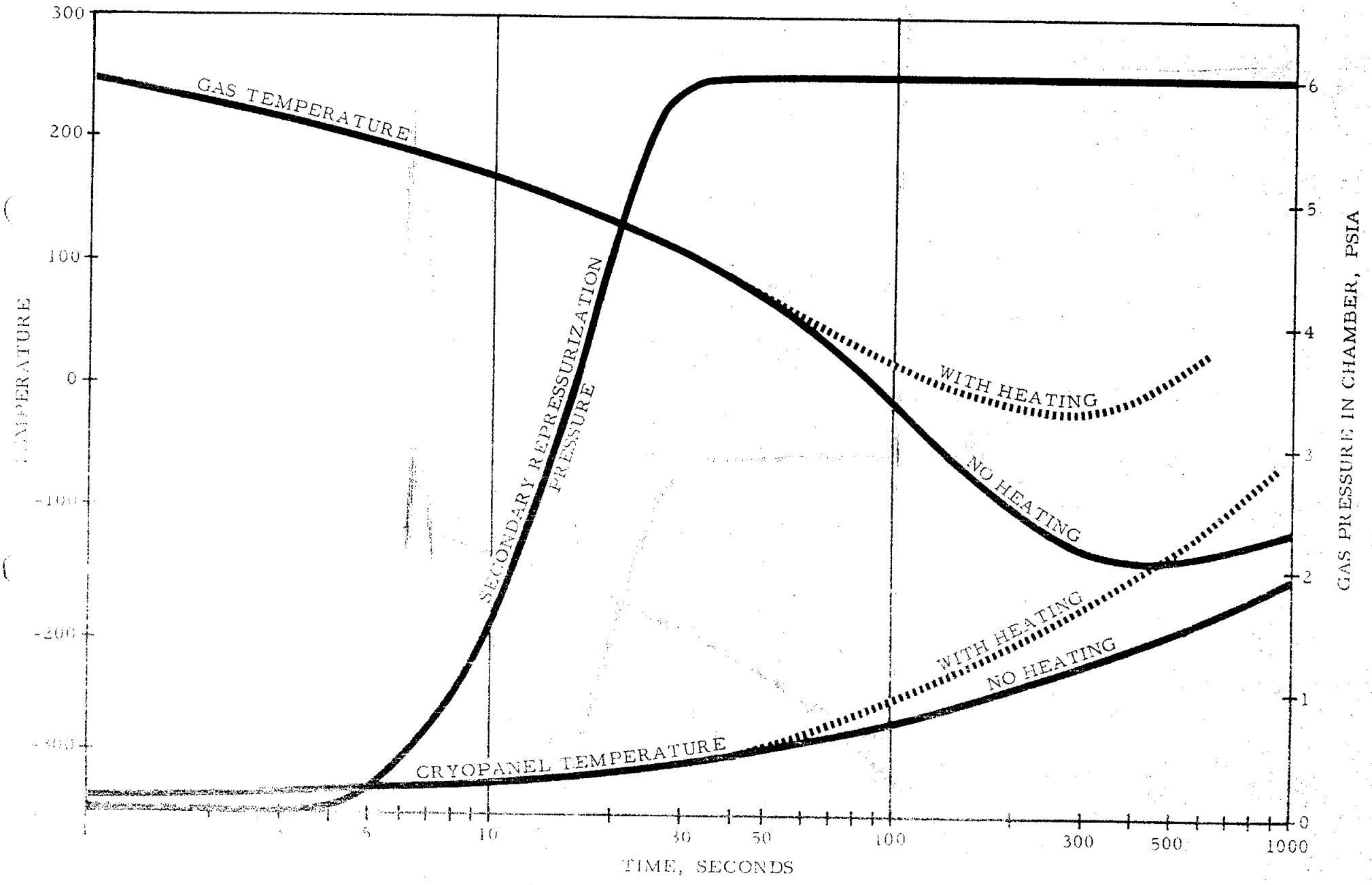



FIGURE 7. TYPICAL PRESSURE TIME PLOT AFTER EMERGENCY REPRESSURIZATION

MEASUREMENTS

(ON BODY AND IN SUIT)
- EKG
- EMG
- EEG
- GSR
- RESPIRATION RATE
- BODY TEMPERATURE
- SKIN TEMPERATURE
- SUIT CIRCUIT TEMPERATURE
- SUIT CIRCUIT PRESSURE
- $CO_2$ PRESSURE
- $O_2$ PRESSURE
- ELECTRODES
- THERMISTORS
- MICROPHONE (HEART BEAT)
- T.V. CAMERA

CABIN
- CABIN TEMPERATURE
- CABIN HUMIDITY
- CABIN PRESSURE
- $O_2$ STORAGE QUANTITY
- $O_2$ STORAGE PRESSURE
- $O_2$ PARTIAL PRESSURE
- REFRIGERATION LOOP TEMPERATURE
- REFRIGERATION LOOP PRESSURE

REVIATIONS

EKG = ELECTROCARDIOGRAM
EMG = ELECTROMYOGRAM
EEG = ELECTROENCEPALOGRAM
GSR = GALVANIC SKIN RESPONSE

SYSTEM SUPERVISORY PANEL

FUNCTION
- MONITORING

INSTRUMENTS

PHYSIOLOGICAL
(SUBJECT MONITORING)
- OSCILLOSCOPE
- HEART RATE
- BLOOD PRESSURE
  - SYSTOLIC
  - DIASTOLIC
- RESPIRATION RATE
- BODY TEMPERATURE (MULTI)
- SKIN TEMPERATURE (MULTI)

ECOLOGICAL
- CABIN TEMPERATURE
- CABIN HUMIDITY
- CABIN PRESSURE
- $O_2$ STORAGE QUANTITY
- $O_2$ STORAGE PRESSURE
- $O_2$ STORAGE TEMPERATURE
- $O_2$ PARTIAL PRESSURE
- $CO_2$ PARTIAL PRESSURE
- REFRIGERATION LOOP TEMPERATURE
- REFRIGERATION LOOP PRESSURE
- SUIT CIRCUIT TEMPERATURE
- SUIT CIRCUIT PRESSURE

AUXILIARY
- PANEL ILLUMINATION
- VIDEO
  - BRIGHTNESS
  - CAMERA SELECTOR
  - CONTRAST
- COMMUNICATIONS
- TIMERS
- PEN RECORDERS
- ANNUNCIATION AND ALARMS

CONDENSED INDICATIONS →

← VOCAL COMMANDS

TEST DIRECTION

FUNCTION
- MONITORING

INSTRUMENTS
- VIDEO
- COMMUNICATIONS
- ANNUNCIATION AND ALARMS
- INDICATION
  - TEMPERATURE (MULTI)
  - PRESSURE (MULTI)
  - OSCILLOSCOPE WITH INPUT SELECTOR

NASA →

e. Figure 9 - Bio-medical measurement of EMG, EEG, or GSR are not contemplated at this time.

FIGURE 9. TYPICAL BIOMEDICAL SYSTEM INFORMATION FLOW DIAGRAM AND CONTROL PANEL DEFINITION

BECHTEL